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CE Or Not CE - That Is The Question

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ABSTRACT

There is tremendous interest in Concurrent Engineering (CE), or Integrated Product and Process Development (IPPD), Integrated Product Teams (IPTs) and other related approaches by U.S. Navy and other U.S. shipbuilders as they look for ways to improve productivity and quality, lower costs and shorten time to delivery.

Unfortunately, as formally defined, CE is not for everyone. The full implementation of CE requires such radical rethinking of and changes in the whole operation of a shipbuilder that many will be unable or unwilling to implement CE. Does this mean that such shipbuilders will be unable to capture shipbuilding orders from the international commercial shipbuilding market? Fortunately not! There are many world class shipbuilders that do not use the formally defined CE approach.

The paper examines the practices of a number of world class shipbuilders and compares them to the CE approach. It then details an approach, Situational Design (SD), based on the concept of applying appropriate techniques and tools to suit the situation. It is also based on the use of a Shipbuilding Policy for each shipyard and a Build Strategy for each ship. It offers this alternative as a way for U.S. shipbuilders to achieve the stated goals of CE without the need to make the radical changes and face the associated risk of a full CE implementation.

NOMENCLATURE

CE	Concurrent Engineering
IPPD	Integrated Product and Process Development
IPT	Integrated Product Team
TQM	Total Quality Management
SD	Situational Design

INTRODUCTION

How can such a question as the title be asked at this symposium? There are books, articles and consultants that all state, to be successful today, companies need to implement Concurrent Engineering (CE). Is this right? Maybe not! It is also timely to ask it as many companies are asking this very question as they investigate and consider how they can improve their performance. Is it possible that there is a way to achieve the high quality, low cost and short delivery time by selectively applying some of the approaches covered by the CE philosophy, without undertaking the radical changes that CE requires? It is hoped that this paper will show that there is.

The author is a proponent of CE and has used it successfully in a number of applications and has helped others to implement it. However, like most remedies, it is not for every company.

The hypothesis of this paper is that while CE can be beneficial and can have a place in the shipbuilding process, it may not be necessary for all stages nor is it the solution for every company. Fortunately, there are other ways to reach the goal of high quality, low cost and short design and build times.

An alternative based on applying the best approach for each situation, or Situational Design (SD) is offered.

To use this alternative approach, it is necessary to benchmark successful practice in many companies. The best approach for a given situation may be one, which is now considered part of CE. It has been suggested by a friend that what is being proposed is the modification of the formally defined CE approach to suit shipbuilding. A number of approaches are discussed, including the Build Strategy approach and suggestions on their use in shipbuilding are provided.

Most books on CE describe the benefits, but also emphasize that CE is not easy to implement, nor is success guaranteed. Many companies have tried to implement CE and failed. Others were unable to sustain the implementation from one project to the next. It has been stated [1] that if a company has tried to implement Total Quality Management (TQM), and failed or even considered it and decided it was not for them, it is pointless for them to even contemplate CE, as it is built on many concepts of TQM.

If one visits successful European and Japanese shipbuilders, the absence of many of the CE attributes is very noticeable. That is, they do not use collocated cross-functional teams and participation of all functions in the early design stages. This is because they do not need them. They do not have the problems to begin with that CE can be used to overcome. Their existing way of working does not have narrow work specialization and department stove pipes with their resulting adversarial relationships, self-interest and internal competition. In addition, a shipyard's processes and desired production practices are well known by their designers.

A number of U.S. shipbuilders are trying to enter the world commercial shipbuilding market, and this raises major challenges for them, such as; how to shorten delivery time, reduce ship prices, and improve the world's perception of U.S. shipbuilding quality.

Some of these U.S. shipyards are looking to CE to assist them meet and overcome the challenges.

The paper first presents a brief description of CE, then discusses some of the difficulties in implementing it. Next, the

type of companies that are successful CE users are examined and the differences between them and the shipbuilding industry are considered. Then the alternative Situational Design (SD) approach is presented. Finally Conclusions and Recommendations for the use of SD are presented.

WHAT IS CE

CE was developed by the U.S. Air Force as part of their Advanced Manufacturing Research. The Air Force wanted to know how some foreign and U.S. companies were able to develop products and deliver them to market faster than most companies. While the Air Force has been successful in applying it to their high cost and long product development cycle situation, in general, its greatest success has been in industries where products may have development cycles of years but delivery cycles of days and even hours, such as the electronic and related industries.

CE is much more than parallel development or the application of a few "in vogue" tools. By definition, it is a totally integrated, concurrent development of product and process design using collocated, cross-functional teams to examine both product and process design from creation to disposal. The essential tenets of CE are customer focus, life cycle emphasis and the acceptance of design ownership and commitment by all team members. There is no longer any engineering problem or purchasing problem. Each problem in any area becomes a problem of the whole team.

All these approaches can be helpful if applied well, but many companies fail to achieve the anticipated benefits. This is most often due to the lack of a logical and integrated implementation sequence that starts from where a company actually is and moves systematically toward the company's long-term goals.

The main objective of CE is to shorten time from order to delivery for a new product at lowest cost and highest quality.

Experience with CE shows it can be of the magnitude required by U.S. shipyards to become competitive in the international commercial shipbuilding market. Customer satisfaction has been improved by 100%, cost reduced by 30% and reduction in design and construction time of 50% [2]. Even though this is a process approach, its success depends on the willingness of people in an organization (top to bottom) to change the way they think and behave. Thus the full implementation of CE offers the potential for big payoff.

CE is not new. The original definition of CE was published in 1970 [3]. Many of the techniques and tools used in CE have been around much longer than CE. However, CE packaged them into an integrated philosophy. This packaging approach can be useful when people do not use the individual techniques and tools, to force them to use them. It is also useful when it is necessary to refocus the efforts of a company, industry and even a country.

CE proponents keep mentioning walls between departments and passing information over the wall. This is one result from the U.S. emphasis on work specialization and is a management problem (organizational design and behavior). CE is an "invention" to overcome the problem. It is suggested that it would be better to eliminate the problem instead. Walls can spring up between cross-functional teams and be just as insidious as walls between departments.

The biggest challenge in implementing CE is being able to successfully bring about the foundation wrenching changes that are necessary in the organization structure and management without destroying the organization. It does not appear, from the experience of many companies, that CE can be implemented gradually and gracefully. In most cases the "all or nothing" approach was required.

The next two biggest challenges in implementing CE are the need to change the company's culture and way of operating. They are both required and reinforce each other. The most visible is the operational change (the way things are done). While it may seem that a company's culture would be visible, this is not so. There are many underlying and conflicting influences that result in a company's "visible" culture. It takes considerable skill and effort to analyze a shipyard's culture, but this is an essential part of the management of change. The change in culture must match the desired mode of operating.

Typical changes require moving from:

- department focus to customer focus,
- directed individual or group to coached team,
- individual interests to team interests,
- autocratic management to leadership with empowered followers, and
- dictated decisions to consensus decisions.

CE involves increased expenditures of time and money "up-front" with the potential benefit of overall improvement in time and cost from better product design.

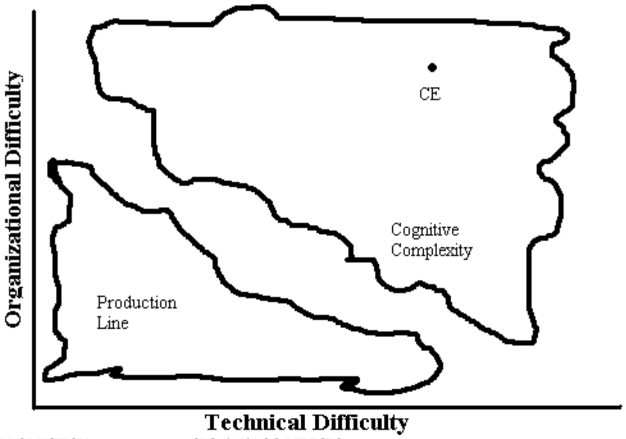
CE DIFFICULTIES

The benefits derived from CE can be radical, but the effort required to bring about the changes required to implement CE can be even greater. These changes are not easy and result in major difficulties for the use of CE. Many companies that attempted to implement CE failed to accomplish it or to achieve any benefit from the attempt. In many of these cases the situation has been well researched and documented in the proceedings of conferences addressing CE and are listed in [1]. These can be read and used by other companies to help understand the extent of the changes that are needed. The most common reason for the failures was the inability of management to effectively manage the introduction of the required changes in their processes and culture.

Ideally, CE involves all the product development participants, including the customer and the company's suppliers, in a team environment, at the start and throughout the design of the product and its processes.

This all-encompassing involvement of all stakeholders is what differentiates CE from other recent improvement approaches. When companies undertake improvement change, they typically want to start with some quick wins. This usually leads them to change something in production where the impact of change can be easily seen in new equipment and/or processes. This can be seen from Figure 1, which shows areas of change on coordinates of Organizational Difficulty versus Technical Difficulty. It shows that production improvement changes are normally made in the low to medium difficulty region and that CE is in the high organizational and medium technology difficulty region. The problem with this approach is that it rarely produces the anticipated improvement because the systems that support production have not improved or even made

any changes. This causes an imbalance in a previously balanced system and results in departments out of sync



PRODUCTION - LINE SPC, ANALOG DEVICES SHORT TIME TO IMPROVE/INFLUENCE

COGNITIVE - NEEDS COORDINATION
COMPLEXITY LONG TIME TO IMPROVE/INFLUENCE

Figure 1 -
Organizational and Technical Difficulty Relationship

with each other. For any change to be successful all of the stakeholders, that is anyone that the change will impact, must be involved, and compatible and supportive changes made in all impacted departments.

There are also two camps in the improvement change field. The first believe that low technology changes must be undertaken before any high technology change is attempted. The second proposes the exact opposite and believes that technology can overcome organizational problems.

The successes of CE are well stated in the many CE books and conference papers. The following are offered as difficulties with CE that can be avoided by the SD approach.

- CE costs more for design and planning and for one-off or small product quantity, and may not be cost competitive or give the shortest design and build time.
- CE is often undertaken only when a company has reached a crisis of survival and then it is often too late.
- CE with its cross-functional teams needs team rewards instead of individual rewards. This has proven to be very difficult to implement.
- Mid-management resists and is reluctant to give up authority to teams.
- Many companies find the investment in systems and personnel change needed to implement CE unacceptable.
- Companies must have a culture that allows changes to work.
- The cooperation, trust and sharing required to successfully implement CE is lacking from current U.S. shipbuilding company cultures.
- To establish teams due to existing cultures that focus on the individual not the group, based on the deep routed U.S. belief in independence.
- Many U.S. shipbuilders are still “telling” organizations, where managers tell workers what to do and do not expect to be challenged.
- Reluctance of individual team members to accept team consensus.
- Need for collocation of teams.
- Lack of a permanent home for team members.
- Lack of clear career path, what happens after team completes task?
- Uncertainty and ambiguity in roles/tasks.
- Resistance to collaboration - communication, cooperation and complete sharing.
- Workers are unable or unwilling to learn new skills.
- Workers are unable or unwilling to accept additional responsibility.
- Need for extensive training of all employees.
- Getting customers, external and internal, on cross-functional teams.
- Requires changes that are transformational, that is fundamental, organization wrenching and far reaching.
- Sustaining the use of CE throughout the life of a product.
- CE is a non-traditional approach to the product development process, and while many of its concepts are logical, its implementation may be perceived by many as radical change and thus generate significant barriers to its acceptance and support.

A excellent discussion of this aspect of CE implementation was presented by Parsaei and Sullivan, [4]. Figure 2 is taken from that reference. It shows the many modes of failure and their relationship to the phases of implementation as well as the influence of management and employees at each mode.

WHO USES CE

The early users of CE were companies that had long product development times but short build times and large quantities of each product to manufacture. These companies were in industries in which time to market was a major success criterion. Being able to design, prototype and deliver products even just a day before your competitors could mean the difference between success and failure of a product. The CE literature has many examples of stories about electronic and consumer

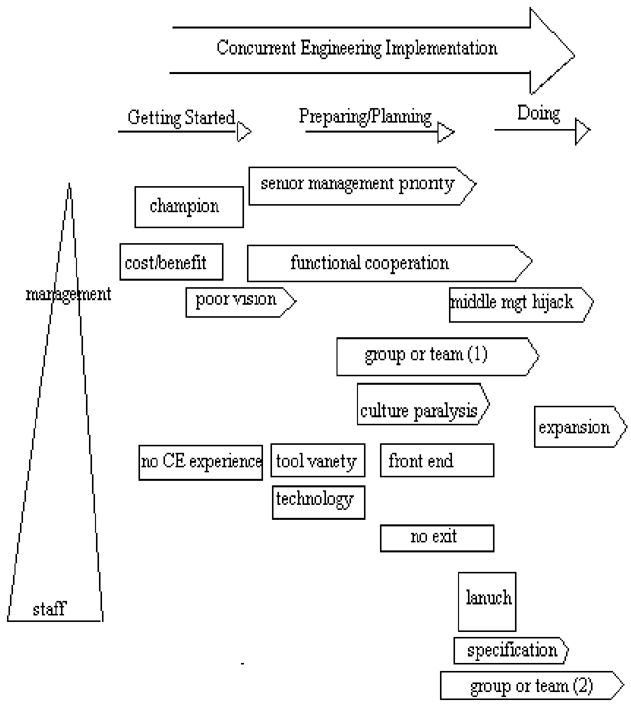


Figure 2 - CE Common Failure Modes

products experiences with CE.

Industries, such as automotive and aerospace, that had even longer development time, involved expensive prototyping, but still had relatively short build times found that CE could reduce the development and prototype time and thus the total time from concept to delivery.

Finally industries, such as shipbuilding and general construction, have latched onto CE as a way to reduce both design and build times and cost of small quantity products.

DIFFERENCES BETWEEN SHIPBUILDING AND OTHER INDUSTRIES

While the "we are different " argument is normally used as a defense against trying something new, it does have some relevance with regard to the implementation of CE. There are significant differences between the shipbuilding industry and other industries that have reported benefits from the use of CE, and it is worthwhile to identify and fully understand them. This will allow shipbuilding management to make a better decision regarding the use of CE.

In some industries the final customer is far removed from the OEM. The automotive industry is such an example where there are distributors and car dealers between them and their customers. Their marketing department uses focus groups and surveys as well as feed back from trade shows. However, the single customer is never considered. It is most unlikely that the typical international commercial ship owner will be willing to commit personnel to a U.S. shipbuilders CE team for 1 to 2 years when foreign shipbuilders can deliver an acceptable ship in the same time without the need and therefore cost of this extra personnel commitment.

Ship engineering has always been parallel development and ship production moved from sequential to parallel some years ago. Block construction and zone outfitting is the move from just parallel to integrated.

CE is the concurrent design of product and process and makes sense when each new product needs completely new processes. Ships do not change much. They are made up from many components that are the same or similar. Shipbuilding facilities are not designed for a single product but are designed to be able to build a range of ship types and sizes. Thus it is not necessary to have cross-functional teams to develop both product and process design concurrently. Functional groups can effectively design the product to suit the previously documented existing processes. Therefore, in shipbuilding the product is usually designed to fit the available processes rather than design new processes.

Success for a new product depends more on making design aware of the processes than getting process designers and product designers together at the same place and time.

Ships are not built on spec or for inventory as are electronic, consumer and automotive products. In shipbuilding, the final customer is in direct contact with the shipbuilder and not separated by distributors and stores.

Compared to other industries there is little uncertainty. Shipbuilders know who will buy and what is wanted and usually do not start until a contract is signed. In shipbuilding there is no need for new models every 2 to 3 years with the resulting changes in processes.

Figure 3: Typical Development Times

YEAR	-5	-4	-3	-2	-1	1	2	3
AUTOMOBILE W/O CE		Product &	Process	Development	Prototype	← Production		
AUTOMOBILE WITH CE				IPPD & 3D	Product Model	← Production		
			←Contract	Award				
AIRCRAFT W/O CE		Product &	Process	Development	Prototype	← Production		
AIRCRAFT WITH CE				IIPD & 3D	Product Model	← Production		
						←Contract	Award	
NAVAL SHIP W/O CE	Formulated Need Prepare Concept & Prel Design				Cont Design	Detailed Design & Production		
NAVAL SHIP WITH CE			IPPD For PRE CD Activities		CD	Detailed Design & Production		
						←Contract	Award	
COMMERCIAL SHIP W/O CE US					Own Dev CD	Detailed Design & Production		
COMMERCIAL SHIP W/O CE Foreign					OD CD	Det Design & Production		

KEY		
	IPPD	INTEGRATED PRODUCT AND PROCESS DEVELOPMENT
	CD	CONTRACT DESIGN
	OD	OWNER DEVELOPMENT

Cradle to grave life cycle focus is most unlikely in commercial shipbuilding as it is normal for the shipbuilder to never see or have any involvement with the ship past the warrantee period. It also means that the designer and even his company will not be involved in these decisions during the ship's operating life.

This does not mean that designers of commercial ships should ignore life cycle costs. Designers must do everything within their control to ensure that ships built will be a success for ship owners.

Industries that appear to benefit most from CE are those with long development and short build times. For example 3 years development, 1 year prototype and 1 month, or less, build times. Commercial shipbuilding is not like this. It has almost equal design and build times with considerable overlapping of design, planning,
purchasing and construction. This is clearly shown in Figure 3.

While the use of 3-D product modeling has the potential to provide virtual prototypes, most shipbuilders are still unlikely to do this, in the foreseeable future, because of its time and cost. In the large product quantity industries, such as automobile and even aircraft, years are taken to design and billions of dollars are spent on special jigs and tooling for each new product. If the design and process are not compatible, considerable additional cost and delay could result. Therefore the product goes through extensive prototyping and testing of functions, as well as build processes, before going into full production.

In this regard, shipbuilding is completely different. It is a small quantity industry that rarely uses prototypes. Construction usually starts before design is complete, even for military ships.

While the time for pre-construction activities can be impacted by approaches such as CE, the build time is more dependent on having a continuous throughput of ships than anything else.

SITUATIONAL DESIGN

There are shipyards in Europe and Japan that build 4 to 6 ships per year, with typical build times of 11 months, with a technical work force of 250 and a production work force of 800 employee's [5]. They are obviously successful from the point of view of time, but it is not possible to say in if they are financially successful due to unclear position
of subsidies. None of them use the formal CE approach.

However, they all have a number of things in common, namely:

- simple functional organization ,
- restricted product range,
- complete documented shipbuilding practice
- focus on one assembly site,
- stable processes,
- effective application of new technology, and internal collaboration rather than internal competition.

They do not have to use CE as they do not have the problems that CE has been developed to overcome. However, these foreign shipyards do not build military ships or even government owned ships, so they are not subject to the long acquisition process generally associated with such ships.

They have used the value generated method, which constantly eliminates non-value added activities, over many years and the result is that they are already a "lean production" organization. They have further become a virtual shipbuilder in that they determined their core competencies and focused on performing them the best they could, and subcontracting most everything else.

This knowledge of foreign shipyard approaches can be used to offer an alternative to the full implementation of CE through the application of Situational Design (SD). SD uses the philosophy that, in shipbuilding, as the product processes do not change for every new product, the need for collocated cross-functional teams for all stages of the design of each new product is eliminated.

Most are familiar with situational management and leadership. For those that are not, it is simply applying different management techniques and leadership styles depending on the situation. Therefore SD is the application of the best "design approach or tool," including some of them now included as part of CE, to fit the situation. An SD decision matrix can be developed to guide the designer as to what approach to
use for different situation problem and stage. The selected approach would change as the situation changed.

A book on organizational flexibility [6] introduced the concept of organizational circles, cones and pyramids and their appropriate use. Table I is developed from the book. Its usefulness to the shipbuilding situation is also shown in the Table. The circle, which emphasizes everyone's involvement in product definition, is used for all design up to bid.

APPROPRIATE ORGANIZATION STRUCTURE	CIRCLE	CONE	PYRAMID
FUNCTION	CLARIFY PROBLEMS GENERATE ALTERNATIVES	PLAN FOR ACTION DESIGN SYSTEMS	IMPLEMENTING PLANS ACCOMPLISH GOALS
ACTIVITY	THINKING TALKING CLARIFING CREATIVE	PLANNING DESIGNING BUILDING	DOING ACTING COMPLETING
PLANNING LEVEL	STRATEGIC	TACTICAL	OPERATIONAL
BUILD STRATEGY APPROACH LEVEL	SHIPBUILDING POLICY	BUILD STRATEGY	
APPROPRIATE APPOACH	CONCURRENT ENGINEERING	PROJECT MANAGEMENT	DEPARTMENTS WORK TEAMS

Table I - Situation Design Guide

The cone, which emphasizes priorities and responsibilities, is used for all remaining design and planning and the pyramid, which emphasizes implementation and monitoring of the design and plan, is used for the actual building of the ship.

Another important aspect is that the different approaches require different management methods and leaders. While this may seem just another view of situational leadership, there is an important difference. Situational leadership recommends that a single manager apply different leadership styles to different situations.

The Flexible Organization approach shows that different managers will be required to fill the different circles, cones and pyramids depending on their predominant leadership style. What that means is that managers must be carefully selected for the different phases.

A useful tool in SD is the Design Structure Matrix [7], which identifies the information flow between activities. This matrix helps to identify:

- information flow between activities;
- best sequence for activities;
- sequential, parallel and coupled activities;
- a logical view of the total process;
- later sequenced activities that provide input to earlier activities; and
- required make-up of cross-functional teams, and impact of changes.

By observing the information flow relationships and the lack of or presence of "clusters," the potential for grouping the activities and applying the best approach (sequential, parallel or coupled) to them is made visible. This can be seen from Figure 4 which shows the author's adaptation of the original matrix as well as in Figure 5 which shows the benefit of the Shipbuilding Policy.

A major factor in the success of the European and Japanese shipyards is the above mentioned documentation of their shipbuilding practices. As expected the extent of the documentation varies depending on the needs of the various shipyards, but they all have it.

The SD approach tries to emulate the successful, simply organized, world class shipyards. It identifies three phases in the ship development cycle, namely Product Definition, Product Development and Product Construction. It uses the circle approach for product definition, the cone approach for product development and the pyramid approach for product construction. It uses many practices now considered part of CE such as cross-functional teams in the product definition phase, project manager and functional groups in the product development phase and either functional groups or work teams in the product construction stage depending on production department culture and skill and education level of the workers. Finally, it uses the formal Build Strategy approach as the foundation on which to build the rest of the system.

The shipbuilding practice books used in Japanese shipyards are well known, but the Build Strategy approach is not as well known, even with the NSRP report on the subject [5]. The A&P Appledore shipyards, in Britain, developed the formal Build Strategy approach just before the British shipbuilding industry was nationalized in the late 70's. It was

		1	2	3	4	5	6	7	INPUTS
PRODUCTION RANGE	**1**	**1**	↑			↑	↑	↑	4
FACILITIES	**2**	↓	**2**	↑		↑	↑	↑	5
PROCESSES	**3**	↓	↓	**3**		↑	↑	↑	5
SHIP DEFINITION	**4**	↓	↓	↓	**4**		↑	↑	5
WORK STATIONS	**5**	↓	↓	↓		**5**	↑	↑	5
PWBS	**6**	↓	↓	↓	↓	↓	**6**	↑	6
INTERIM PRODUCT CAT	**7**	↓	↓	↓	↓	↓	↓	**7**	6
OUTPUTS		6	6	5	2	5	6	6	

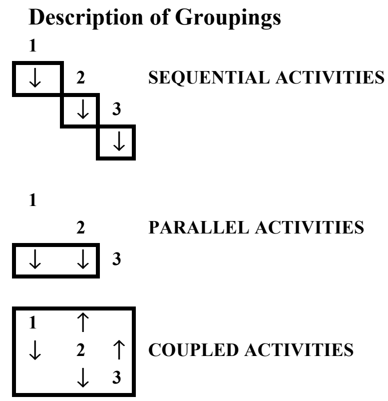


Figure 4 - Design Structure Matrix for Shipbuilding Policy

further developed by the nationalized British Shipbuilders. [8,9]

The formal Build Strategy approach was the subject of an NSRP study [5]. For completeness it is briefly described in this paper with emphasis on the Shipbuilding Policy, for reasons that will become apparent.

A Build Strategy is an agreed design, engineering, material management, production and testing plan, prepared before work starts, with the aim of identifying and integrating all necessary processes.

A Build Strategy is a unique shipbuilding tool. It provides a holistic beginning to end perspective for capturing the combined design and shipbuilding knowledge and processes, so they can be continuously improved, updated, and used as both reference and training tools.

The performance of any endeavor will be improved by improvements in communications, cooperation and collaboration. A Build Strategy improves all three. It communicates the intended total shipbuilding project to all participants. This communication fosters improved cooperation as everyone is working to the same plan. It improves collaboration by involving most of the stakeholders (interested parties) in its development.

The Build Strategy approach incorporates other pre-requisites. This is because, while a Build Strategy can be produced as a stand alone document for any ship to be
built by a shipyard, it will be a great deal thicker and will take a lot more effort to produce than if certain other documents are will not be available. This is clearly shown in the Design Structure Matrices for the Build Strategy approach with and without a Shipbuilding Policy in Figure 4.The first of these documents is the shipyard's Business Plan, which probably exists, in some form, in most shipyards. A Business Plan sets out a shipyard's ambitions, in terms of desired product range, output and build cycles, for a period of years and describes how the shipyard aims to attain them.

The Business Plan sets a series of targets for the technical and production part of an organization. To meet these targets, a set of decisions is required on:

- facilities development,
- productivity targets,
- production organization and methods,
- planning and contract procedures,
- make-buy and subcontractor policy, and
- technical and production organization.

These form the core of the Shipbuilding Policy which is the other required document. The shipbuilding policy has a hierarchy of levels, which allow it to be applied in full at any time to a particular contract. The shipbuilding policy defines, for the product mix, which the shipyard intends to build, the optimum organization,
and procedures, which will allow it to produce ships efficiently.

The shipbuilding policy also contains the Ship Definition. The Ship Definition is a detailed description of the procedures to be adopted, and the information and format of that information to be produced by each department developing technical information within a shipyard. The ship definition must reflect the manner in which the work is to be performed and make full use of the physical and procedural standards that have been adopted. The ship definition specifies the format and content that the engineering information will take in order to support the manner in which the ships will be built. The engineering information provided to the

WITH SHIPBUILDING POLICY

		1	**2**	**3**	**4**	**5**	**6**	**7**	**INPUTS**
SHIPBUILDING POLICY	**1**	**1**							0
PRELIMINARY DESIGN	**2**	↓	**2**						1
CONTRACT DESIGN	**3**	↓	↓	**3**					2
BUILD STRATEGY	**4**	↓		↓	**4**				2
PRODUCTION DESIGN	**5**	↓		↓	↓	**5**			3
OPERATIONAL PLANNING	**6**	↓			↓	↓	**6**		3
PRODUCTION	**7**	↓				↓	↓	**7**	3
OUTPUTS		7	1	2	2	2	1	0	

WITHOUT SHIPBUILDING POLICY

		1	**2**	**3**	**4**	**5**	**6**	**INPUTS**
PRELIMINARY DESIGN	**1**	**1**						0
CONTRACT DESIGN	**2**	↓	**2**	↑				2
BUILD STRATEGY	**3**		↓	**3**	↑			2
PRODUCTION DESIGN	**4**		↓	↓	**4**			2
OPERATIONAL PLANNING	**5**			↓	↓	**5**		2
PRODUCTION	**6**					↓	**6**	1
OUTPUTS		1	2	3	2	1	0	

Figure 5 - DSMs for Build Strategy Approach with and without a Shipbuilding Policy

production department should only include that necessary for them to perform the work in the assigned work stations.

The description must ensure that the information produced by each department is in a form suitable for the users of that information. The Ship Definition will detail the methods for breaking the ships in the product mix into standard interim products by applying a Product-oriented Work Breakdown Structure (PWBS). It will also incorporate a shipyard's Interim Product Catalog. Areas in which the interim products will be produced and the tools and procedures to be used will also be defined.

An essential prerequisite for successful block and zone approach is the use of PWBSs. An NSRP publication outlined their need, use and the experience of Japanese shipyards [10]. A companion paper to be presented at this symposium reports on more recent developments of PWBSs and interim products (11).

A major objective of the Shipbuilding Policy is design rationalization and standardization. This is achieved by the application of Group Technology and the PWBS to form families of interim products having similar manufacturing requirements.

Most manufactured products are assembled from many components, both manufactured by and purchased by the assembler. All of these components can be viewed as "interim products."

Most shipbuilders view a ship as being composed of many interim products. Each interim product is the output of a work stage, and are combined with other interim products until the ship is complete.

Many shipbuilders have used the interim product concept along with Group Technology to group the interim products for the range of ship types and sizes that they build into families, either by interim product geometry or process. This has resulted in classification and coding of their interim products into a catalog.

Initially, this catalog was simply descriptive, but has grown to become a communication tool for estimators, designers, planners and production workers. Today, interim product catalogs not only describe the product and/or processes, but include preferred process, next preferred alternative process, process required resources, stage of construction, parametric standard times, and any other useful characteristic.

The use of an interim product catalog has many benefits to a shipbuilder. It:

- promotes product and process standardization ,
- simplifies process planning,
- promotes stable processes,
- supports product based estimating, and
- provides a clear definition of process flows.

As such, it is easy to see how the interim product catalog is a natural and essential part of the proposed Ship Definition.

The relationship between the Business Plan, Shipbuilding Policy and Build Strategy is shown in Figure 6.

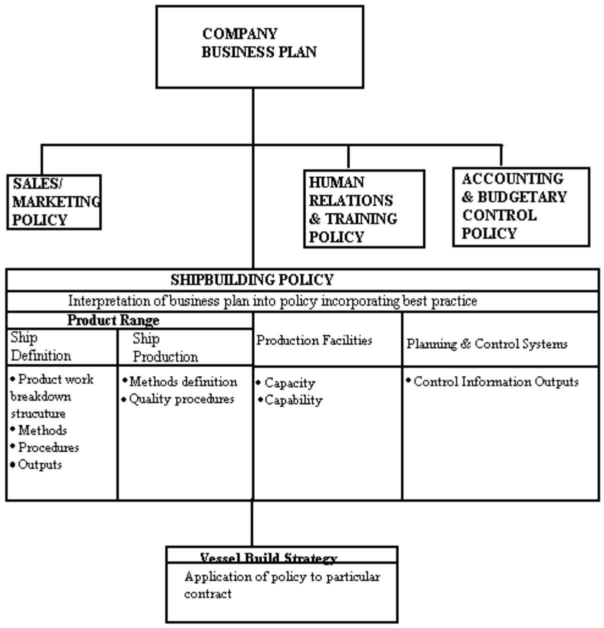


Figure 6 - Relationship of Business Plan, Shipbuilding Policy and Build Strategy

In essence, the Shipbuilding Policy comprises a set of standards, which can be applied to specific ship contracts. The standards apply at different levels:

- Strategic, related to type plans, planning units, interim product types, overall facility dimensions, and so on; applied at the Conceptual and Preliminary Design stages;
- Tactical, related to analysis of planning units, process analysis, standard products and practices, and so on; applied at the Contract and Transition Design stages;
- Operational, related to work station operations and accuracy tolerances; applied at the Detail Design stage.

Work at the strategic level provides inputs to:

- the conceptual and preliminary design stages,
- contract build strategy,
- facilities development,
- organizational changes, and
- the tactical level of shipbuilding policy.

Documents are prepared which address the preferred product range. For each vessel type, the documents include:

- definition of the main planning units,
- development of type plans, showing the sequence of erection, and
- analysis of main interim product types.

The strategic level also addresses the question of facility capability and capacity.

Documentation providing input to the preliminary design stage includes:

- preferred raw material dimensions,
- maximum steel assembly dimensions,
- maximum steel assembly weights,
- material forming capability, in terms of preferred hull configurations,
- "standard" preferred outfit assembly sizes, configuration and weights, based on facility
- capacity, and
- "standard" preferred service routes.

At the tactical level standard interim products and production practices related to the contract and transition design stages, and to the tactical planning level are developed. All the planning units will be analyzed and broken down into a hierarchy of products.

The shipbuilding policy will define preferences with respect to standard:

- interim products,
- product process and methods,
- production stages,
- installation practices,
- material sizes, and
- piece parts.

The capacity and capability of the major shipyard facilities is also be documented. For the planning units, sub-networks are developed which define standard times for all operations from installation back to preparation of production information. These provide input to the planning function.

At the Operational level, a shipbuilding policy provides standards for production operations and for detail design.

The documentation includes workstation:

- descriptions,
- capacity,
- capability,
- design standards,
- accuracy control tolerances,
- welding standards, and
- testing requirements.

For the planning units, sub-networks are developed which define standard times for all operations from

1.0 OVERVIEW 1.1 Objectives 1.2 Purpose and Scope **2.0 PRODUCT RANGE** 2.1 Product Definition 2.2 Outline Build Methods **3.0 OVERALL PHILOSOPHY** 3.1 Outline 3.2 Planned Changes and Developments 3.3 Related Documents 3.4 Work Breakdown Structure 3.5 Coding 3.6 Technical Information 3.7 Workstations 3.8 Standards 3.9 Quality Assurance 3.10Accuracy Control **4.0 PHYSICAL RESOURCES** 4.1 Outline 4.2 Planned Changes and Developments 4.3 Related Documents 4.4 Major Equipment 4.5 Steel Preparation and Subassembly 4.6 Pipe Manufacture 4.7 Outfit Manufacture 4.8 Steel Assembly 4.9 Outfit Assembly 4.10 Block Erection 4.11 Engineering Department **5.0 SHIP PRODUCTION METHODS** 5.1 Outline 5.2 Planned Changes and Developments 5.3 Related Documents 5.4 Standard Interim Products, Build Methods, 5.5 Critical Dimensions and Tolerances 5.6 Steel Preparation	5.7 Steel Assembly 5.8 Hull Construction 5.9 Outfit Manufacture 5.10 Outfit Assembly 5.11 Outfit Installation 5.12 Painting 5.13 Services 5.14 Productivity Targets 5.15 Subcontract Work **6.0 SHIP DEFINITION METHODS** 6.1 Outline 6.2 Planned Changes and Developments 6.3 Related Documents 6.4 Ship Definition Strategy 6.5 Pre-Contract Design 6.6 Post-Contract Design 6.7 Engineering 6.8 Work Station Documentation **7.0 PLANNING FRAMEWORK** 7.1 Outline 7.2 Planned Changes and Developments 7.3 Related Documents 7.4 Strategic Planning 7.5 Tactical Planning 7.6 Operational Planning 7.7 Performance Monitoring and Control **8.0 HUMAN RESOURCES** 8.1 Outline 8.2 Planned Changes and Developments 8.3 Related Documents 8.4 Organization 8.5 Training 8.6 Safety **9.0 ACTION PLAN** 9.1 Outline 9.2 Projects and Time scales

TABLE II - TYPICAL LIST OF CONTENTS IN A SHIPBUILDING POLICY DOCUMENT

installation back to preparation of production information. These provide input to the planning function.

Because shipbuilding is dynamic, there needs to be a constant program of product and process development. As with all levels of the shipbuilding policy, the standards should be updated over time, in line with product development and technological change. Also, the standards to be applied change over time with product type, facility, and technology development.

Table II shows typical contents of a Shipbuilding policy.

The shipbuilding policy is therefore consistent, but at the same time undergoes through a structured process of change, in response to product development, new markets, facilities development, and other variations.

Again, many of the CE techniques can be effective at this stage to ensure the involvement of all departments.

Therefore, to link current policy with a future policy, there should be a series of projects for change which are incorporated into an overall action plan to improve productivity. Since facilities are a major element in the policy, a long term development plan should exist which looks to a future policy in that area. This will be developed against the background of future business objectives, expressed as a plan covering a number of years.

Many U.S. shipyards and the U.S. Navy are now strong proponents of the Build Strategy approach, but few, if any, of them develop a Shipbuilding Policy. This is difficult to understand as the Shipbuilding Policy is the most important part of the Build Strategy approach.

To be successful in today's international shipbuilding market, a shipyard should design its facilities around a specific product range and standard production methods which are supported by a variety of technical and administrative functions that have been developed according to the requirements of production. These would be described and captured in the Shipbuilding Policy. Then whenever new orders are received only work, which is

significantly different from any previously undertaken needs to be investigated in depth in order to identify possible difficulties. There is no hesitation in getting started as it is known how the shipyard will process all the work from preliminary design through testing and delivery. There is no need for meetings to hammer out new agreements between departments or to “reinvent the wheel. With the processes well known throughout the shipyard, decisions can be made at the appropriate levels, leaving the managers time to work with other managers on new strategic plans.

Without a Shipbuilding Policy key players must meet at the start of each new project to decide what will be done and who will do it.

The next level in the hierarchy defines the set of strategies by which this policy is realized, namely the Build Strategy.

The Build Strategy is a "seamless" document. That is, it crosses all traditional department boundaries. It is an important step in the direction of the seamless enterprise. The most evident benefit is improved communication brought about by engaging the whole company in discussions about project goals and the best way to achieve them.

It should bring up front, and be used to resolve, potential conflicts between departments in areas of design details, manufacturing processes, make or buy decisions, and delivery goals.

It eliminates process or rework problems due to downstream sequential hand-over of tasks from one department to another by defining concurrently how the ship will be designed and constructed.

The Build Strategy:

- applies a company's overall shipbuilding policy to a contract;
- provides a process for ensuring that design development takes full account of production requirements;
- systematically introduces production engineering principles that reduce ship work content and cycle time;
- identifies interim products and creates product-oriented approach to engineering and planning of the ship;
- determines resource and skill requirements and overall facility loading;
- identifies shortfalls in capacity in terms of facilities, manpower and skills;
  creates parameters for programming and detail planning of engineering, procurement and production activities;
- provides the basis on which any eventual production of the product may be organized including procurement dates for long lead material items;
- ensures all departments contribute to the strategy;
- identifies and resolves problems before work on the contract begins; and
- ensures communication, cooperation, collaboration and consistency between the various technical and production functions.

The very act of developing a Build Strategy has benefits because it requires the various departments involved to communicate, and to think rationally about how and where work for a particular contract will be performed. It also highlights any potential problems and enable them to be addressed well before the "traditional" time when they arise.

The shipbuilding policy should be examined in order to ascertain if a ship of the type under consideration is included in the preferred product mix. If such a ship type does fit, then certain items will already have been addressed. These items include:

- outline build methods,
- work breakdown structure,
- coding,
- workstations,
- standard interim products,
- accuracy control,
- ship definition methods,
- planning framework,
- physical resources at shipyard, and
- human resources.

One thing, which is unique to any new ship order, is how it fits in with the ongoing work in a shipyard. The current work schedule must be examined in order to fit the ship under consideration into this schedule. Key dates, such as cutting steel, keel laying, launch and delivery will thus be determined.

Using the key dates other events can be planned. These events are:

- key event program,
- resource utilization,
- material and equipment delivery schedule,
- material and equipment ordering schedule,
- drawing schedule,
- schedule of tests and trials, and
- stage payment schedule and projected cash flow.

Once the major events and schedules are determined, they can be examined in detail to expand the information into a complete build strategy. For example, the key event program can be associated with the work breakdown to produce planning units and master schedules for hull, blocks, zones, equipment units, and systems.

The Build Strategy Document should be used by all of the departments in the shipyard, and a formal method of feedback of problems and/or proposed changes must be in place so that agreed procedures cannot be changed without the knowledge of the responsible person. Any such changes must then be passed on to all holders of controlled copies of the Build Strategy.

CONCLUSIONS

1. Whatever approach is used, the essential ingredient to success in today’s global industries is continuous learning and improvement.
2. To accomplish change it is useful to have a framework or system to provide the required discipline. This is what CE and other approaches based on linking existing tools and techniques do.
3. As defined, CE requires radical changes to the way a company functions, including company culture, management, worker involvement, cross-functional teams, collocation and other management/worker interface aspects, that many companies are unable or unwilling to undertake.
4. CE has been proven to be very beneficial for products that are manufactured in large quantities, have long development time

but short build time, such as cars and electronic equipment. CE has also proven useful for medium quantity products that have long acquisition cycles, such as military aircraft and tanks.

5. CE is currently being applied to small quantity and even longer acquisition cycle warships.
6. The CE approach does not have to be applied cradle to grave. It can be successfully applied to specific stages in a products life cycle. However, it must have clear goals and a clearly defined beginning and end.
7. CE has had a meaningful benefit in bringing the many internal and external players in the naval ship development process together and made them aware of how they need to improve.
8. CE has helped U.S. Navy shorten the pre-contract acquisition time
9. CE has been judged successful in many situations not because it made a good system better, but because it improved a bad situation.
10. Many of the problems that CE is designed to overcome can be resolved by other approaches.

RECOMMENDATIONS

1. Fully understand what a shipyard is trying to do and establish goals before deciding to implement CE.
2. Look at why change is needed.
3. Concentrate on eliminating activities rather than improving them.
4. Look at other alternatives to CE and understand the different levels of change required.
5. Use SD to select the best approaches and integrate them with the Build Strategy approach.
6. Select the alternative that has the best potential for success both in acceptance and improvement.
7. Remember that matching the right response to the situation is critical for success in implementing change.
8. Use the Design Structure Matrix to identify the best sequencing and grouping of activities.
9. CE should be used for activities where "circular" approaches are used, such as the development of the Shipbuilding Policy and even the first time a Build Strategy is prepared.

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REFERENCES

1. *NSRP REPORT*, 1994, Concurrent Engineering Application, by T. Lamb

2. CARTER, D. E., et al, *CE Concurrent Engineering: The Product Development Environment for the 1990's,* Addison-Wesley, Reading, MA, 1992

3. IDA Report R-338, The Role of Concurrent Engineering in Weapon System Acquisition, December 1988

4. PARSAEI, H. R. and SULLIVAN, W. G., editors *Concurrent Engineering*, Chapman & Hall, New York, 1993

5. LAMB, T., et al "Build Strategy Development, NSRP Symposium, Seattle, 1994

6. FORISHA-KOVACH, B., *The Flexible Organization*, Prentice-Hall Inc., N.J. 1984

7. HUOVILA, P. et al, Concurrent Engineering Applications in Construction, ACE96 Seattle

8. CRAGGS, J. D. F., "Build Strategy Development," SPC/IREAPS Technical Symposium, 1983

9. *NSRP REPORT*, 1994, "Build Strategy Development," by T. Lamb & J. Clark

10. *NSRP REPORT*, 1982, "Product Work Breakdown Structure," by L. D. Chirillo.

11. KOENIG, P., et al, "Towards a Generic Product-oriented Work Breakdown Structure for Shipbuilding," NSRP Symosium, New Orleans, 1997

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